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Losses Associated With Douglas-Fir and True Fir Tops Killed by Western Spruce Budworm in Eastern Washington

Paul E. Aho

Author

PAUL E. AHO is a research plant pathologist, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, Corvallis, Oregon 97331.

Abstract

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Keywords: Insect damage (-forest, increment (height), crown damage, decay (wood), heartwood rot, western spruce budworm, Douglas-fir, *Pseudotsuga menziesii,* true fir, *Abies* spp., Washington (eastern), eastern Washington.

Research Summary

From 1970 to 1979, the western spruce budworm (WSBW) (*Choristoneura occidentalis* Freeman) caused extensive damage on the Wenatchee and Okanogan National Forests in Washington by defoliating 1.2 million acres of Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) and true firs (*Abies* spp.). Severe defoliation often kills the tops of attacked trees. In this study, losses in height and losses caused by decay associated with defoliation of Douglas-fir and true fir tops by western spruce budworm are estimated. Estimates extrapolated from other studies of treetops killed by WSBW or tussock moth in other areas may not be applicable on these Forests.

A sample of 133 Douglas-firs from 14 stands and 69 true firs from 9 of these stands were studied to determine height and decay losses associated with top damage caused by defoliation by the WSBW. Negligible losses in height were observed for both species when only the last year or two of growth of treetops was killed. Lateral branches quickly assumed dominance and formed new tops. Height losses of trees severely damaged by top-kill averaged 4.3 feet for Douglas-fir and 4.4 feet for true firs. Regrowth of tops by lateral branches was about 1 foot for both species. Apparently lateral branches lower in the tree are less vigorous than those nearer the original treetop or trees with extensive top-kill were so severely damaged by the effects of defoliation that the laterals could not respond.

Only three of the sample trees with dead tops were infected by decay fungi. Average basal diameter of dead tops was less than 1 inch. Only 7 percent of all trees studied with top-kill had basal diameters larger than 2 inches. More than four-fifths of all the top-killed trees had been dead fewer than 6 years—too little time for extensive decay to develop. Only five dead tops, all true firs, had also been attacked by bark beetles.

Decay losses associated with dead tops should be low on the Wenatchee and Okanogan National Forests if conditions in most defoliated stands are similar to those in the 14 sampled stands.

Introduction

From 1970 to 1979, western spruce budworm (WSBW) (*Choristoneura occidentalis* Freeman) caused extensive damage on 1.2 million acres of Douglas-fir and true firs on the Okanogan and Wenatchee National Forests in Washington (Harvey 1982). Damage varied from minor defoliation to top-killing to tree mortality. An evaluation was conducted in 1980 to quantify stand volume losses caused by the WSBW infestation. Volume lost as dead tops in trees attacked by WSBW and from subsequent decay of living stems below dead tops has not been evaluated in Washington. In addition, height losses caused by top-killing and the portion of a "dead top" actually dead have not been quantified.

In Canada, Stillwell (1956) found 0.5 to 23 feet of decay in living crowns of balsam fir below tops killed by eastern spruce budworm 35 years earlier. In grand fir in Idaho, Ferrell and Scharpf (1982) found columns of decay typically from 2 to 3 feet long below tops killed by WSBW over 57 years. One dead top resulted in cull of the entire tree.

In a study of decay losses associated with tops killed by Douglas-fir tussock moth (*Orgyia pseudotsugata* McDonnough) defoliation, little deductible defect was associated with top-kill of white fir in California after 33 years (Wickman and Scharpf 1972). In 1979 in eastern Oregon and Washington, Aho and others found 4.8 percent of the gross cubic-foot volume decayed in living grand fir stems below tops killed 2 to 35 years before by tussock moth defoliation.

In this study, the losses in height and decay caused by WSBW top-killing Douglas-fir and true firs on the Okanogan and Wenatchee National Forests are estimated. Extrapolation of estimates from similar studies in other areas or States may not be applicable on these Forests. Tops that appeared to be dead were examined to determine what proportion were still alive.

Methods

The study was planned to be conducted in a randomly selected subsample of stands from a study conducted by Forest Pest Management (FPM) of the Pacific Northwest Region of the USDA Forest Service, "Effects of western spruce budworm infestation on stand volume on the Okanogan and Wenatchee National Forests." The data were to be tied to FPM's evaluation of the stands. Because the FPM stands could not be destructively sampled, similar stands close to those being evaluated by FPM had to be found.

Selection of Study Stands and Trees

From stands that were close to the FPM stands and that had been severely defoliated by the western spruce budworm up to 10 years before, 14 stands were sampled in the Okanogan and Wenatchee National Forests (table 1).

Inland Douglas-fir was a component of all stands sampled, whereas true firs occurred in only nine. True fir species were: grand fir (*Abies grandis* (Dougl. ex D. Don) Lindl.), Pacific silver fir (*A. amabilis* Dougl. ex Forbes), and subalpine fir (*A. lasiocarpa* (Hook.) Nutt.).

Table 1—Douglas-firs and true firs with or without dead tops sampled in 14 stands attacked by western spruce budworm in the Wenatchee and Okanogan National Forests

Ranger District and stand	Douglas-fir tops			True fir tops		
	Not dead	Dead 1/	Not visible 2/	Not dead	Dead 1/	Not visible 2/
	Number of trees					
WENATCHEE NATIONAL FOREST						
Cle Elum Ranger District:						
Cooper Lake	1	5	2	0	6	3
Little Creek	0	5	3	0	5	3
Thorp Creek	0	6	3	0	4	3
Ellensburg Ranger District:						
First Creek	1	6	2	0	5	3
Porky Basin #1	1	3	4	1	6	2
Porky Basin #2	0	3	5	0	5	4
Leavenworth Ranger District:						
The Icicle	1	5	2	1	5	3
OKANOGAN NATIONAL FOREST						
Conconully Ranger District:						
Cabin Creek	3	4	5	0	0	0
Funk Mountain	1	5	3	3	4	1
Rusty Creek	6	8	2	0	0	0
State Cabin Road	3	5	1	1	5	2
Twisp Ranger District:						
Little Bridge Creek	1	8	8	0	0	0
Winthrop Ranger District:						
Goat Wall	1	8	7	0	0	0
Eightmile Creek	1	8	7	0	0	0
Total	20	79	54	6	45	24

1/ Dead top visible from ground before tree was felled.

2/ Dead top not visible until tree was felled and dissected.

Results and Discussion

Because data from this study were to be applied to standing trees examined by FPM field crews, it was important to note whether or not damaged tops could be seen before trees were felled. In most of the stands sampled, it was nearly impossible to differentiate between trees with healthy and dead tops while trees were standing, unless a spike top protruded above the live crown. Many trees had their tops killed in the past, but over time, a lateral branch had assumed dominance to form a new top. The dead tops, in most cases, were hidden from ground view in the live crown.

Attempts were made to locate three apparently healthy and five top-killed Douglas-fir and true firs in each stand sampled. Where only Douglas-fir or true fir occurred, the sampled was doubled (6 healthy and 10 top-killed) for the species present. In some stands, all trees with top-kill had to be sampled because of the small population of trees with visible damage. In most stands, however, selection could be made from a large number of trees with dead tops. A representative sample was selected from a range of trees based on size of trees and of top-kills.

Standing sample trees were carefully examined by use of binoculars to determine top damage, evidenced by spike, bayonet, forked, or crooked tops. If no damage was seen, the top was considered "healthy," even if the top was found to be dead after the tree was felled and dissected. Diameter of trees at breast height (4.5 feet) was measured, and other indicators of decay were noted while trees were still standing.

Dissection and Measurement of Trees

Selected trees were felled at a stump height of 6 inches and dissected into 16-foot logs to a top d.i.b. (diameter inside bark) of 4 inches (for cubic volume measurement) and to a top d.i.b. of 6 inches for trees 11.0 inches and greater in d.b.h. (diameter at breast height) to determine board-foot volume according to Aho and others (1979). Age of trees was determined by a ring count at stump height.

The height growth of trees without visible top damage was measured by yearly increments for the last 15 years in feet and tenths. Cuts were made at each node, and rings were counted to check ages determined earlier. By use of this system, the years when a tree did not grow in height (probably because of defoliation by the WSBW) could be determined.

For trees with top damage, the type of damage (broken, spike, bayonet, forked, crooked tops), height to the base of the dead top, basal diameter and length of the killed top, length and diameter of new leaders, secondary damage from insects, and extent of decay below and above the base of the dead tops were recorded. Each apparently dead top was carefully examined to see if the cambium and buds at the tips of lateral branches were actually dead. Length of live portions of "dead" tops was noted. The age (year of origin) of the top damage was determined by comparing ring counts from disks cut immediately below, at, and above the top-killed portion. Logs were further dissected to measure extent of decay from other causes.

Isolation of Decay Fungi

Culture blocks, about 27 cubic inches in size, were taken at the base of and just below the dead top and from wherever discoloration or decay was found, usually near other indicators. Blocks were placed in an ice chest or were refrigerated until they were taken to the laboratory. The blocks were split with a sterile chisel, and two small chips (about 3 mm^3) were aseptically removed and placed on malt agar slants in test tubes. The tubes were incubated on a bench at room temperature. The types of micro-organisms isolated were noted after an incubation of 6 weeks.

Decay Associated With Dead Tops

Basic data for the 133 Douglas-firs with top damage are summarized in table 2. The top damage in 54 trees was not visible when viewed from the ground (table 1). Only one dead top was infected by decay fungi (table 2). Loss from decay was negligible. The incidence of infection by decay fungi was probably limited by the small size of the tops and the recent origin of the damage. Average basal diameter was 0.5 inch, and age of dead tops was 5 years. Only 6 percent of the basal diameters of the tops killed were larger than 2 inches. Nearly 80 percent of the tops had been dead fewer than 6 years.

Five columns of decay, associated with injuries other than top damage, were found in the Douglas-firs (table 2). Cubic- and board-foot volumes lost because of these infections were small.

In the nine stands of true firs sampled, 69 trees with dead tops were studied. Only two tops were infected by decay fungi and, as with the Douglas-fir sample, loss of volume was small (table 3). Infection by decay fungi was probably low because of the small basal diameters, the recency of top-killing, and the low incidence of a secondary attack by beetles. Average diameter at the base of dead tops was 0.9 inch, and only six diameters (9 percent) were larger than 2 inches. Aho and others (1979), in a study of decay associated with grand fir tops killed by Douglas-fir tussock moth defoliation, found low levels of infection and decay in dead tops with basal diameters of less than 2 inches.

Average length of time the tops had been dead was 5 years (table 3). Only 11 tops (16 percent) were dead more than 5 years. The two top-kills infected by decay fungi were 8 and 11 years old.

Table 2—Basic data for 133 Douglas-firs top-killed by the western spruce budworm in 14 stands in the Wenatchee and Okanogan National Forests

Stand name	Trees with dead tops	Infected dead tops		Average diameter of tree		Average diameter of top-kill		Cubic-foot volume associated with top-kill			Board-foot volume associated with top-kill			Decay not associated with top-kill: Total infections	Decay not associated with top-kill: Cubic-foot volume		Decay not associated with top-kill: Board-foot volume	
															Total	Percent of gross	Total	Percent of gross
				O.b.h.	Age	Base	Age	Gross	Decay	Decay	Gross	Decay	Decay					
	No.	No.	%	In	Yr	In	Yr	- - Ft^3 - -		%	Board feet		%	No.	- - Ft^3 - -		Board feet	
Porky Basin #1	7	0	0	8.0	67	0.4	5	63.5	0	0	102	0	0	0	0	0	0	0
The Icicle	7	1	14	8.6	99	1.0	6	89.7	.1	.1	301	0	0	0	0	0	0	0
Porky Basin #2	8	0	0	9.7	74	.5	6	99.5	0	0	326	0	0	1	.1	.1	0	
Little Bridge Creek	16	0	0	12.2	92	.6	6	415.2	0	0	1,527	0	0	0	0	0	0	0
Eightmile Creek	15	0	0	11.1	126	.4	6	251.7	0	0	925	0	0	1	0.3	.5	18	1.9
Goat Wall	15	0	0	10.7	150	.3	6	197.9	0	0	506	0	0	3	.6	.3	7	1.4
State Cabin Creek	6	0	0	7.4	139	.1	3	27.7	0	0	0	0	0	0	0	0	0	0
Funk Mountain	8	0	0	8.4	68	.1	2	48.4	0	0	40	0	0	0	0	0	0	0
Cabin Creek	9	0	0	8.3	73	.1	3	64.6	0	0	0	0	0	0	0	0	0	0
Rusty Creek	10	0	0	9.3	75	.2	2	98.2	0	0	144	0	0	0	0	0	0	0
Cooper Lake	7	0	0	10.3	77	.8	3	94.7	0	0	163	0	0	0	0	0	0	0
Thorp Creek	9	0	0	9.7	92	1.3	4	104.9	0	0	139	0	0	0	0	0	0	0
First Creek	8	0	0	9.1	68	1.2	4	75.4	0	0	143	0	0	0	0	0	0	0
Little Creek	8	0	0	8.8	76	.5	4	72.9	0	0	217	0	0	0	0	0	0	0
Total or average	133	1	.8	9.8	95	.5	5	1,704	.1	0	4,533	0	0	5	2.0	.1	25	.6

Table 3—Basic data for 69 true firs top-killed by the western spruce budworm in 9 stands in the Wenatchee and Okanogan National Forests

Stand name	Trees with dead tops	Infected dead tops		Average diameter of				Cubic-foot volume associated with top-kill			Board-foot volume associated with top-kill			Decay not associated with top-kill				
				Tree		Top-kill								Total infections	Cubic-foot volume		Board-foot volume	
				D.b.h.	Age	Base	Age	Gross	Decay	Decay	Gross	Decay	Decay		Total	Percent of gross	Total	Percent of gross
	No.	No.	%	In	Yr	In	Yr	- - Ft^3 - -		%	Board feet		%	No.	- - Ft^3 - -		Board feet	
Porky Basin #1	8	1	12.5	9.5	60	1.2	6	94.1	0.5	0.5	309	3	1.0	2	0.3	0.3	0	0
The Icicle	8	0	0	8.4	105	1.1	8	74.3	0	0	0	0	0	4	.4	.4	0	0
Porky Basin #2	9	1	11.1	9.5	76	1.1	4	69.7	.1	0	205	0	0	5	.5	.5	1	.7
State Cabin Road	7	0	0	7.3	48	.2	1	38.1	0	0	0	0	0	0	0	0	0	0
Funk Mountain	5	0	0	7.2	68	.3	3	21.8	0	0	0	0	0	1	.1	.5	0	0
Cooper Lake	9	0	0	7.7	71	.4	3	62.7	0	0	0	0	0	0	0	0	0	0
Thorp Creek	7	0	0	8.0	90	1.1	5	65.7	0	0	102	0	0	0	0	0	0	0
First Creek	8	0	0	8.0	60	1.5	4	56.0	0	0	0	0	0	0	0	0	0	0
Little Creek	8	0	0	10.0	68	.6	3	154.4	0	0	504	0	0	0	0	0	0	0
Total or average	69	2	2.9	8.5	77	.9	5	636.9	.6	.1	1,120	3	.3	12	1.3	.2	1	.1

Aho and others (1979) found that incidence of infection and volumes of wood decayed were significantly greater when grand fir tops were killed by tussock moth defoliation and were also attacked by bark beetles and wood borers than when tops were killed by defoliation only. In this study, only five top-kills (7 percent) of true fir had also been attacked by beetles. The two dead tops infected by decay fungi had been attacked by bark beetles and wood borers. These results agree with those found by Basham (1980) in his study of deterioration of balsam fir (*Abies balsamea* (L.) Mill.) killed by spruce budworm. All trees in stands heavily attacked by bark beetles had advanced sap rot 1 to 2 years after death, but no advanced sap rot was found in dead balsam firs in stands with little beetle activity.

Twelve infections by decay fungi were associated with injuries, mainly trunk wounds, other than top damage (table 3). As with the Douglas-fir sample, little decay was caused by these infections.

The only fungi capable of causing decay were isolated from the three dead tops that had columns of associated rot. Both decay columns in true fir trees were caused by *Pholiota limonella* (Pk.) Sacc. *Fomitopsis cajanderi* (Karst.) Kitl. et Pouz. was responsible for the decay associated with the only infected Douglas-fir dead top. Most microorganisms isolated were fast-growing, nonhymenomycetous fungi. Bacteria were also frequently isolated.

Proportion of "Dead" Tops Actually Dead

Entomologists have noticed that some portions of tops that appeared dead have put on new foliage in succeeding years.[1] In this study, 27 percent of apparently dead Douglas-fir tops and a quarter of true fir top-kills were not completely dead. The average length of apparently dead Douglas-fir tops was 1.6 feet. Average length of the tops actually dead was 1.3 feet. The difference between the apparent top length and the actual dead length for true firs was 0.5 foot (1.9 vs. 1.4 feet). In most cases, the difference between the length of apparent and actual dead tops was only a few tenths of a foot; however, in some circumstances the difference was substantial. For instance, a dead Douglas-fir top appeared to be 8.3 feet long, but the cambium and branch tips were dead only 3.8 feet back from the tip. Similar observations were made in the true fir sample.

[1] Personal communication from Robert D. Harvey, Jr., USDA Forest Service, Pacific Northwest Region, Portland, Oregon.

Height Losses

When only the last year or two of the tops of Douglas-firs or true firs are killed by western spruce budworm defoliation, little height growth is lost because a lateral branch quickly assumes dominance and forms a new treetop. When defoliation causes a treetop to die back several years, height growth loss is more severe. Average height losses of severely top-killed trees (the last 3 or more years of growth was killed) were 4.3 feet for Douglas-fir and 4.4 feet for true firs. Regrowth of tops by lateral branches was 0.9 foot for Douglas-fir and 1.1 feet for the true firs. Laterals lower in the tree are less likely to express dominance or are slower to, perhaps because they are less vigorous than the younger laterals near the original top or because the trees with extensive top-kill were so badly damaged by defoliation that the laterals could not respond.

Williams (1967) has shown that there is a differential effect on severity of top-kill damage to host tree species defoliated by WSBW. True firs (grand and subalpine firs) are apparently more severely top-killed than are Douglas-fir by budworm defoliation. Such a difference was not observed in this study, possibly because of a lack of a secondary attack by bark beetles on species of either genus.

Conclusions

Decay losses associated with top-kill of Douglas-fir and true firs caused by western spruce budworm defoliation were very low in the Wenatchee and Okanogan National Forests up to 10 years after the infestation subsided. Incidence of infection and extent of decay have been limited by the small basal diameters of tops, the recency of damage, and the lack of secondary attack by beetles. There did not appear to be a differential effect of damage on host species as reported by others.

If conditions in most stands severely defoliated by the WSBW in the Wenatchee and Okanogan National Forests are similar to those found in the 14 stands sampled, decay losses associated with dead tops should be very low. If deductions for decay are to be made, they should be made for dead tops with large basal diameters (>2.0 inches) and for secondary attacks by beetles. Even under these conditions, decay losses would be low because the tops have not been dead long enough for extensive columns of rot to develop.

Acknowledgment

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Metric Equivalents

1 inch = 2.54 centimeters
1 foot = 0.3048 meter
1 cubic foot = 0.028 32 cubic meter
1 acre = 0.4047 hectare

Literature Cited

Aho, Paul E.; Wickman, Boyd E.; Roe, Lee. Decay in tops killed by Douglas-fir tussock moth in the Blue Mountains. Res. Pap. PNW-250. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1979.** 22 p.

Basham, J. T. Preliminary report on the rate of deterioration of spruce-killed balsam fir, and its relationship to secondary stem insects. Rep. 0-X-314. Sault Ste. Marie, ON: Department of the Environment, Canadian Forestry Service, Great Lakes Forest Research Centre; **1980.** 20 p.

Ferrell, George T.; Scharpf, Robert F. Stem volume losses in grand firs topkilled by western spruce budworm in Idaho. Res. Pap. PSW-164. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station; **1982.** 10 p.

Harvey, Robert D., Jr. Loss assessment western spruce budworm infestation on the Okanogan and Wenatchee National Forests. Eval. Rep. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; **1982.** 36 p.

Stillwell, M. A. Pathological aspects of severe spruce budworm attack. For. Sci. 2:174-180; **1956.**

Wickman, B. E.; Scharpf, R. F. Decay in white fir top-killed by Douglas-fir tussock moth. Res. Pap. PNW-133. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; **1972.** 9 p.

Williams, Carroll B., Jr. Spruce budworm damage symptoms related to radial growth of grand fir, Douglas-fir, and Engelmann spruce. For. Sci. 13(3):274-285; **1967.**

Aho, Paul E. Losses associated with Douglas-fir and true fir tops killed bv western spruce budworm in eastern Washington. Res. Pap PNW-318. Portland, OR: U.S. Department of Agriculture, Forest Service. Pacific Northwest Forest and Range Experiment Station **1984.** 8 p.

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Pacific Northwest Forest and Range
Experiment Station
809 N.E. Sixth Avenue
P.O. Box 3890
Portland, Oregon 97208